



# Forest Research Technical Report

**Vancouver Forest Region**

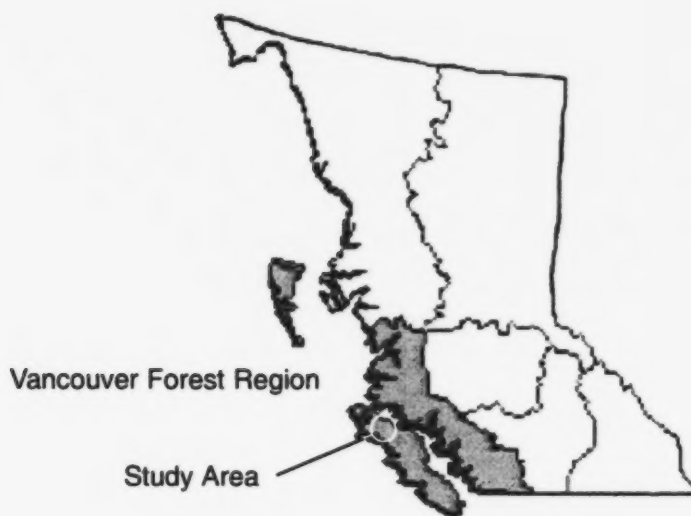
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## **The Value of Riparian Forest Buffers as Habitat for Birds in the Coastal Western Hemlock Zone, British Columbia: a Pilot Study**

by

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## EXECUTIVE SUMMARY

During the breeding bird season of 1994 we studied bird communities in riparian and upland habitats along 20-40 m wide S1 rivers (Forest Practices Code; Government of BC 1995). We used point count surveys to detect birds in old-growth forest (>250 years) and we mapped territories of breeding birds both in old-growth forest and in pre-Code riparian forest buffers of young plantations. The study sites were distributed between a watershed in the Submontane Very Wet Maritime Coastal Western Hemlock variant (CWHvm1) and a watershed in the Very Dry Maritime Coastal Western Hemlock subzone (CWHxm), both on northeastern Vancouver Island, British Columbia. The abundance and diversity of species was not consistent between the two watersheds, and these differences may in part reflect differences between the prevailing ecosystems of the watersheds.

Overall, in the old-growth forest, Hammond's Flycatchers were associated with the riparian edge, but we did not identify any bird species as being dependant on the river for habitat. Winter Wrens, Red Crossbills, and Varied Thrushes were in greater abundance in upland habitats. Total number of individuals and number of species (species richness) were significantly greater in the upland. These differences may in part be attributable to some species having home ranges that extend beyond the riparian area, some species selecting habitats at a finer scale (e.g., using riparian habitats on smaller streams in the upland), or sampling limitations in detecting rarer species in the narrow riparian zone.

The maximum number of species detected in the old-growth was within 350 m of the rivers, suggesting wider buffers may better maintain the old-growth bird community. Many species used both riparian and upland habitats, and this overlap of species assemblages further supports the suggestion that riparian and upland should be managed together to provide bird habitat. In addition, the one-sample comparison in our study between a wide riparian forest buffer (mean ~85 m) and the narrower buffers (<30 m) also indicates that wider buffers likely support more of the old-growth associated species.

We found that young plantations with riparian forest buffers, narrow or wide, only retained a portion of species associated with the old-growth forest. Yet in these young plantations, species richness compared to that in old-growth was maintained because new species occupied the newly created buffer edge and open habitats. Furthermore, we found that old-growth associated bird species were more likely to occupy those riparian forest buffers isolated within plantations on both sides of the river, than those buffers limited to one side of the river across from old-growth.

We suggest that these isolated double buffers may provide poorer quality habitat for some bird species but are used because the availability of old-growth forest is limited, whereas single buffers are not as likely to be used with birds accessing higher quality habitat across the river. If so, the habitat potential of riparian buffers may be enhanced for birds – without exceeding Forest Practices Code regulations on riparian management area widths – if single buffers are used in conjunction with old-growth or mature second-growth stands across the river.

In summary, the protection of both the riparian edges in buffers along the river provides for important habitat over the long term, although only a portion of the old-growth associated bird community will be retained at the stand level, at least in the short term. Present regulations for riparian reserve zones (50 m) and adjacent riparian management zones (20 m) on these S1 rivers will likely provide better bird habitat than the pre-Code buffers (<50 m) that we studied because wider buffers appear to maintain more bird species associated with old-growth.

## KEY WORDS:

*Bird community, old-growth forest habitat, riparian forest buffer, buffer width, riparian management area*

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## 1 INTRODUCTION

Riparian areas adjacent to flowing aquatic ecosystems provide high-quality habitat for foraging, breeding, and movement of some wildlife species (Raedeke 1988, Knopf and Samson 1994, LaRue et al. 1995, Voller 1998). Generally, the riparian area includes that area influenced by flowing water both outward on the ground and upward into the canopy (Gregory et al. 1991, Government of British Columbia 1995).

Yet the transition from riparian to upland can be subtle in some forested ecosystems because of high densities of streams, entrenched reaches, and patchy distributions of flood plain habitats (Gregory et al. 1991). As well, the contrast between riparian and upland is less marked in wet climates than in dry climates. Streams are a water source for terrestrial animals, but the high-quality habitat of the riparian area is also attributable to the riparian forest edge interface produced by the juxtaposition of water and vegetation. The riparian area thus has a unique microclimate, a more complex vertical vegetation structure, and site-specific plant species (Raedeke 1988, Gregory et al. 1991, Voller 1998).

Previous management of riparian areas specified in the British Columbia Coastal Fisheries/Forestry Guidelines (Province of

British Columbia 1993) focused on the retention of narrow riparian forest buffers to protect aquatic values such as water quality and fish habitat. Since 1993, management objectives have expanded to also include retaining riparian forest buffers for both ecological values – for example, recruitment of instream large woody debris (LWD) – and wildlife habitat (Government of British Columbia 1995). Riparian forest buffers may provide corridors for linking wildlife habitats, as well as provide breeding and foraging habitat (Rosenberg et al. 1997).

However riparian forest buffers have the potential to become fragments of isolated forest types within managed landscapes dominated by younger seral stages. Habitat quality may be reduced for some species in these buffers because of isolation, loss of forest interior conditions, limited habitat availability, attraction of new species, or increased densities of species (species packing) (Wiens 1995). Buffer width is therefore an important criterion for meeting management objectives, as well as for ensuring long-term retention of the buffer (Government of British Columbia 1995).

This pilot study examines the habitat values of riparian forest buffers for forest birds (Rosenberg et al. 1997). Birds are useful for habitat research because they are easily identified through aural and visual methods, and their communities reflect the diverse array of habitat needed for foraging and nesting (Martin and Geupel 1993). The types of plant species and the structure of vegetation in riparian habitat may provide more opportunities for breeding birds to nest than those in upland habitats (LaRue et al. 1995). The microclimate (more moisture, sunlight, and stable temperatures) of riparian habitats could also enhance the reproductive success of birds, while diverse and abundant invertebrate and plant communities enhance their foraging base (Gray 1993, Knopf and Samson 1994).

The study was undertaken during the breeding bird season. Its objectives were:

- to identify bird species that depend on riparian habitats of rivers (>20 m width, S1 (Province of British Columbia 1995)) in coastal old-growth (>250 years) forest;
- to determine differences in bird abundance and bird community structure between riparian habitats adjacent to rivers and the adjacent upland in coastal old-growth forest;
- to compare bird communities between old-growth forest and young plantations (less than four years after harvest) managed with riparian forest buffers;
- to compare bird communities of riparian forest buffers when the opposing side of the river was old-growth forest (single narrow buffer) and when the opposing side of the river was another young plantation with a riparian forest buffer (double narrow buffer – an isolated fragment); and
- to evaluate how the width of buffers affects the value of riparian areas as habitat for birds.

## 2 STUDY AREA

The study areas were located along the middle reaches of the Tsitika and Davie Rivers in coastal old-growth forest on

northeastern Vancouver Island, British Columbia. Both of these rivers flow at low elevations in the Coastal Western Hemlock (CWH) biogeoclimatic zone (Meidinger and Pojar 1991, Green and Klinka 1994). The CWH is a broad ecosystem ranging from sea level to 600 m elevation on windward slopes (Meidinger and Pojar 1991).

The Tsitika R. is within the Submontane Very Wet Maritime Coastal Western Hemlock variant (CWHvm1), while the Davie R. is within the Very Dry Maritime Coastal Western Hemlock subzone (CWHxm). The CWHvm1 is characterized by cool, wet summers and mild winters. It is dominated by western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), and lesser amounts of western redcedar (*Thuja plicata*) with an understory shrub layer of red huckleberry (*Vaccinium parvifolium*) and Alaskan blueberry (*Vaccinium alaskaense*) (Green and Klinka 1994). The CWHxm has warm, dry summers (with potential water deficits on some sites) and moist, mild winters. Douglas-fir (*Pseudotsuga menziesii*) dominates these sites, with western hemlock and minor amounts of western redcedar, while the understory includes a shrub layer of salal (*Gaultheria shallon*), Oregon grape (*Mahonia nervosa*), and red huckleberry (Green and Klinka 1994).

## 3 METHODS

To assess the value of riparian forest buffers as habitat for forest birds during May and June of the 1994 breeding season, we used two common methods to measure bird abundance and community structure: point count surveys, and mapping of territories in study blocks (Verner 1985, Bibby et al. 1992).

### 3.1 POINT COUNT SURVEYS

We used point count surveys to determine whether bird abundance and diversity changed with distance from the river in old-growth forest stands. In accessible old-growth forest, we randomly placed six transects in the Tsitika R. watershed and five in the Davie R. watershed (Table 1). Survey points with centres 125 m apart (slope distance) were positioned at four distances (50, 175, 300 and 425 m) on a transect perpendicular to the river edge (Fig. 1a). All birds aurally or visually detected within a fixed radius (50 m) at each survey point were recorded during a 12-minute

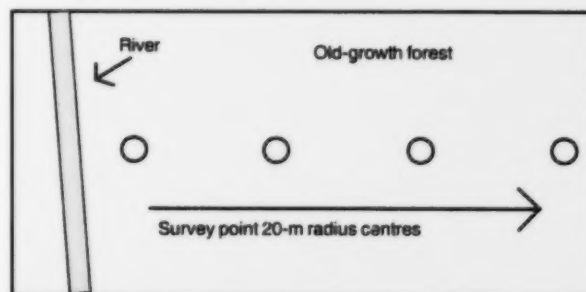


**Figure 1a.** Schematic of 50 m radius survey points located perpendicular to the river at 50, 175, 300, and 425 m slope distance.

**Table 1.** Distribution of 50-m radius forest bird survey points used in the Tsitika R. and Davie R. watersheds. Survey points were repeated by transect lines perpendicular to the river banks (measured as slope distance).

| Survey Points | Distance to river<br>position | Tsitika R.<br>number of transects | Davie R.<br>number of transects | Total survey<br>points<br>per position* |
|---------------|-------------------------------|-----------------------------------|---------------------------------|-----------------------------------------|
| A             | 50                            | 6                                 | 5                               | 11                                      |
| B             | 175                           | 6                                 | 5                               | 11                                      |
| C             | 300                           | 6                                 | 5                               | 11                                      |
| D             | 425                           | 6                                 | 3*                              | 9                                       |

\*transect lines with survey points at the 4 distances repeated by 9 lines were only included in the ANOVA, n=36 survey points

period. Observers visited each survey point four times during the breeding season, within four hours after sunrise.

From the four surveys, the maximum number of detections of all birds using the forest – expressing maximum potential use by the community – was used to calculate the modified Shannon-Wiener diversity index (base 10). The Shannon-Wiener index ( $H'$ ) is a measure of species richness and abundance that indicates how difficult it may be to correctly predict the species of the next individual collected. For example, a community consisting of merely one species would have no uncertainty, thus its diversity will equal 0 (Zar 1984, Krebs 1989). The modified index ( $N1$ ) is the number of equally common species that would produce the same diversity as  $H'$  (Krebs 1989).

The mean number of detections from the four surveys, as a better estimate of breeders rather than immigrants or young, was used to calculate abundance of individual species. To determine significant differences between the two areas and among the four distance positions from the river edge, we used a completely randomized, split-plot design, analysis of variance (ANOVA) in JMP 3.2 (SAS Institute 1997). Watershed is the main plot factor and position is the split-plot factor (Figure 2). Several variables were rank- or log-transformed to achieve normally distributed residuals with constant variance. The ANOVA was not applied to those species with fewer than five observations.

Next, we calculated power for those (untransformed) variables

that lacked significant results at  $\alpha=0.05$ . We estimated a practical difference of 0.5 mean abundance for common species (approximately two additional observations of a species per survey point); 0.3 mean abundance for rare species or those with large territories (approximately one additional observation of a species per survey point); and three for community measures (approximately three more species per survey point for richness and three more individuals per survey point for total individuals, or three more equally common species for modified Shannon-Wiener diversity).

### 3.2 TERRITORY MAPPING

We examined habitat use of the riparian forest buffers by mapping breeding territories in study blocks of approximately five hectares (25 x 25 m grids; minimum 250 m in length and adjusted to fit each buffer perpendicular to the slope; maximum 200 m in width parallel to the slope; all measurements as slope distances; Figure 1b, Table 2).

First, in each watershed, we located a control study block adjacent to the river in unharvested old-growth forest. Next, we placed a treatment study block in each watershed, in a young plantation (<4 years) with a riparian forest buffer that opposed uncut old-growth forest on the other side of the river (hereafter referred to as a single narrow buffer). We then located a treatment study block in each watershed in a young plantation with a riparian

**Figure 2.** ANOVA table used for testing for significant differences between positions of survey points (50, 175, 300, 425 m) and riparian edge, where watersheds = Tsitika R. and Davie R.

| Source                          | Degrees freedom | Error term                      |
|---------------------------------|-----------------|---------------------------------|
| watershed                       | 1               | transect (watershed)            |
| transect (watershed)            | 7               | -----                           |
| position                        | 3               | transect (watershed) x position |
| watershed x position            | 3               | transect (watershed) x position |
| transect (watershed) x position | 21              | -----                           |

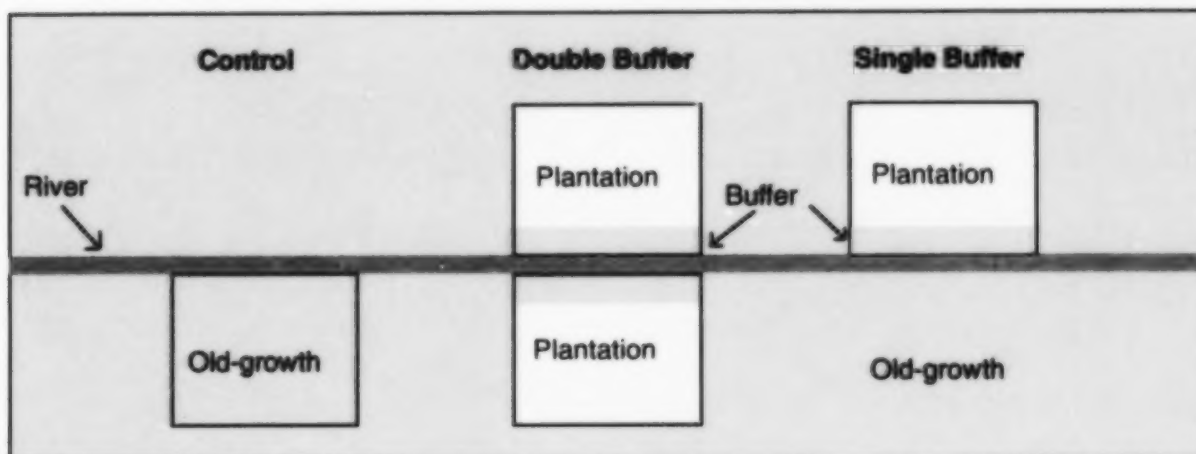


**Figure 1b.** Schematic of river in old-growth forest showing an unharvested control block, a double narrow buffer study block, and a single narrow buffer study block. Each study block only included one side of the river, and was measured as slope distance. To incorporate the available buffer a minimum width of 250 m was used and 200 m slope distance into the plantation.

forest buffer that opposed another riparian forest buffer in a young plantation on the other side of the river (hereafter referred to as a double narrow buffer). Study blocks in the watersheds ranged from 500 m to five km apart. The buffer widths (<50 m) and lengths (<1000 m) varied because the study was designed post-harvest (Table 2). On the Tsitika R., we used an additional treatment study block as a double buffer site because the buffer in this study block ranged from 50 to 120 m in width, and this enabled us to compare a narrow to a wide buffer (hereafter referred to as a double wide buffer).

Observers surveyed each study block eight times over the breeding season, within four hours after sunrise. A cluster of three or more territorial behaviours (singing, breeding, aggression) defined individual territories on each species' map for purposes of calculating the number of territories per species per study block (Verner 1985). Data analysis only included descriptive statistics because of the limited number of replicates ( $n=2$ ). We used Renkonen percent similarity – where percent similarity between sites is 100% only if all the same species occur in the same abundance – to compare richness (number of species) and overlap of these species (1) between the different treatments within each watershed and (2) between the two

watersheds for the same treatment (Krebs 1989).

## 4 RESULTS

Along each river edge were small pockets of scattered high bench floodplain sites (high bench floodplain sites are generally described as site series 09, Green and Klinka 1994). The riparian habitat was characterized by dense (40-80% <2 m height, <20% 2-10 m height), variable-width vegetation bands (<20 m in width) of below-canopy shrubs (false azalea *Menziesia ferruginea*, salmonberry *Rubus spectabilis*, red huckleberry, Alaskan blueberry) and deciduous trees (alder *Alnus rubra*). In general, the transition from riparian to upland was relatively uniform with the observable riparian zone mostly confined to within 20 m of the river edge, although microclimate effects may have extended beyond 20 m.

### 4.1 POINT COUNT SURVEYS

#### 4.1.1 WATERSHED EFFECTS

A total of 31 bird species (Appendix A) were detected in the old-growth forest of both watersheds using point count surveys.

**Table 2.** Description of treatments used for comparing species richness and numbers in unlogged forests and in plantations retaining riparian forest buffers for two watersheds: Tsitika R. and Davie R.

| Study Block          | Acronym | Year after harvest |          | Size (ha)* |          | Buffer Width (m) |          | Buffer Area (ha) |          | Buffer Length (m) |          |
|----------------------|---------|--------------------|----------|------------|----------|------------------|----------|------------------|----------|-------------------|----------|
|                      |         | Tsitika R.         | Davie R. | Tsitika R. | Davie R. | Tsitika R.       | Davie R. | Tsitika R.       | Davie R. | Tsitika R.        | Davie R. |
| Control              | CN      | n/a                | n/a      | 5.6        | 5.2      | n/a              | n/a      | n/a              | n/a      | n/a               | n/a      |
| Double Narrow Buffer | DN      | 2                  | 2        | 4.4        | 5.4      | 5-30             | 10-25    | 0.44             | 1.05     | 285               | 525**    |
| Single Narrow Buffer | SN      | 4                  | 1        | 4.1        | 5.4      | 5-8              | 25-50    | 0.13             | 0.92     | 250               | 250      |
| Double Wide Buffer   | DW      | 2                  | n/a      | 5.5        | n/a      | 50-120           | n/a      | 2.40             | n/a      | 250               | n/a      |

\*Area includes harvested and unharvested forest

\*\*~100 m of buffer on a stream < 5 m wide draining into the river

Twenty-two species were detected within 100 m of the rivers. Four additional species (Song Sparrow, Merlin, Marbled Murrelet, and Common Raven) were detected within 125-225 m; another four (Northern Flicker, Pileated Woodpecker, Red-breasted Nuthatch, and Rufous Hummingbird) were detected within 250-350 m; and one additional species, the Western Tanager, was found at 450 m. The occurrence of the Western Tanager at this location may have been influenced by the riparian edge of a nearby lake shore.

The abundance of several species differed between the two watersheds. At 95% significance, both community diversity and the mean abundances of Dark-eyed Juncos, Hammond's Flycatchers, and Townsend's Warblers were greater in the Davie R. watershed, while mean abundances of Pacific-slope Flycatchers, Red Crossbills, and Winter Wrens were greater in the Tsitika R. watershed (Table 3). Mean abundance of the

Brown Creeper was within the 90% level of significance in the Davie R. watershed (no power test) and Hermit Thrushes were within the 90% level of significance within the Tsitika R. watershed. For those species with non-significant values, the power of the ANOVA for the given sample size was not adequate for detecting the estimated practical difference in mean abundance between the two watersheds (Table 3).

#### 4.1.2 DISTANCE TO WATER

There were few significant differences (Table 4, Figure 3) between individual species abundance and distance to water (50, 175, 300, 425 m). At the 95% level of significance, the richness of species and mean abundance of two species, Hammond's Flycatcher and Red Crossbill, were significantly associated with position on the transect. Hammond's Flycatchers were more abundant closer to the river, while the mean abundance of Red

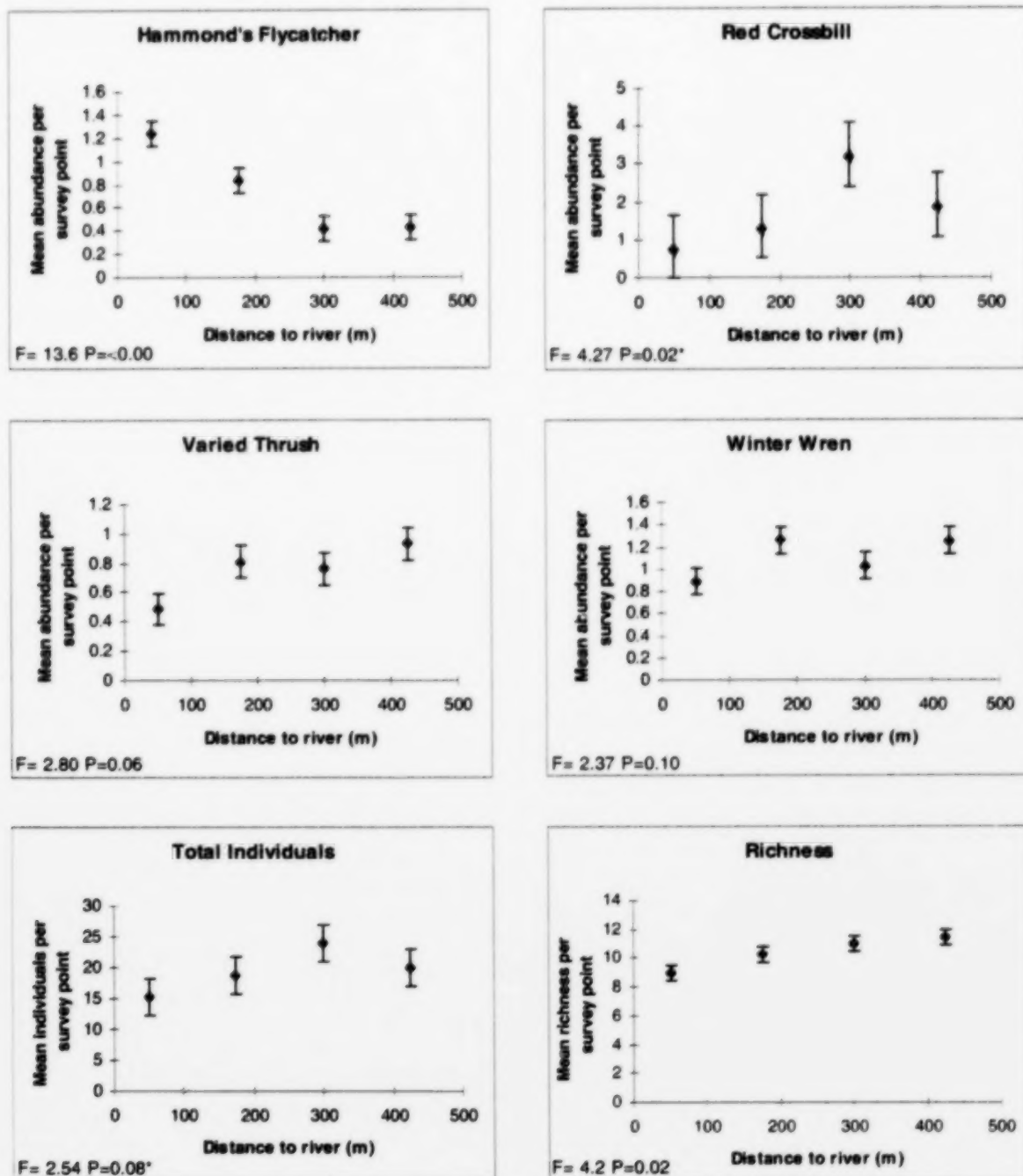
**Table 3.** Results from the completely randomized split-plot design analysis of variance and power tests for the main plot factor Watershed using species' abundance, richness, and diversity. Retrospective power is calculated for a practical difference (range) of: 0.3 mean abundance for rare species or those with large territories; 0.5 mean abundance for common species; and 3 for community measures at  $\alpha=0.05$  (untransformed data only).

| Species                                                                             | Watershed |                      | Greater mean abundance per survey point (%) |       |                     |
|-------------------------------------------------------------------------------------|-----------|----------------------|---------------------------------------------|-------|---------------------|
|                                                                                     | F         | P-value <sup>1</sup> | Range                                       | Power | Tsitika R. Davie R. |
| American Robin                                                                      | 1.6       | 0.25                 | 0.5                                         | 0.6   |                     |
| Brown Creeper <sup>2</sup>                                                          | 4.9       | <b>0.06</b>          | n/a                                         | n/a   | >                   |
| Chestnut-backed Chickadee                                                           | 0.1       | 0.77                 | 0.5                                         | 0.1   |                     |
| Dark-eyed Junco                                                                     | 12.0      | <b>0.01</b>          | n/a                                         | n/a   | >                   |
| Golden-crowned Kinglet                                                              | 0.1       | 0.83                 | 0.5                                         | 0.2   |                     |
| Hammond's Flycatcher                                                                | 199.1     | <b>&lt;0.0001</b>    | n/a                                         | n/a   | >                   |
| Hairy Woodpecker                                                                    | 2.1       | 0.19                 | 0.3                                         | 0.5   |                     |
| Hermit Thrush                                                                       | 4.2       | <b>0.09</b>          | 0.5                                         | 0.8   | >                   |
| Pine Siskin <sup>2</sup>                                                            | 1.9       | 0.22                 | n/a                                         | n/a   |                     |
| Pacific-slope Flycatcher                                                            | 8.2       | <b>0.03</b>          | n/a                                         | n/a   | >                   |
| Red-breasted Sapsucker                                                              | 0.1       | 0.73                 | 0.3                                         | 0.1   |                     |
| Red Crossbill <sup>2</sup>                                                          | 9.3       | <b>0.02</b>          | n/a                                         | n/a   | >                   |
| Steller's Jay                                                                       | 0.0       | 0.92                 | 0.3                                         | 0.6   |                     |
| Swainson's Thrush                                                                   | 0.9       | 0.77                 | 0.5                                         | 0.1   |                     |
| Townsend's Warbler                                                                  | 9.0       | <b>0.02</b>          | n/a                                         | n/a   | >                   |
| Violet Thrush                                                                       | 2.0       | 0.20                 | 0.5                                         | 0.1   |                     |
| Vaux's Swift                                                                        | 1.6       | 0.25                 | 0.3                                         | 0.5   |                     |
| Winter Wren                                                                         | 7.0       | <b>0.03</b>          | n/a                                         | n/a   | >                   |
| Total individuals <sup>3</sup>                                                      | 1.4       | 0.28                 | n/a                                         | n/a   |                     |
| Species richness                                                                    | 2.4       | 0.17                 | 3                                           | 0.2   |                     |
| Modified Shannon-Wiener diversity                                                   | 16.6      | <b>0.005</b>         | n/a                                         | n/a   | >                   |
| rank transformed data                                                               |           |                      |                                             |       |                     |
| log transformed data                                                                |           |                      |                                             |       |                     |
| <sup>1</sup> P <sub>2</sub> 0.05 is bolded, 0.05 < P <sub>2</sub> 0.1 is italicized |           |                      |                                             |       |                     |

**Table 4.** Results from the completely randomized, split-plot design ANOVA and power tests for the split-plot factor Position (50, 175, 300, 425 m) using species' abundance, richness, and diversity. Retrospective power is calculated for a practical difference (range) of: 0.3 mean abundance for rare species or those with large territories; 0.5 mean abundance for common species; and 3 for community measures at  $\alpha=0.05$  (untransformed data only).

| Species                                                                                                                                                    | Position |                      |       |                        |                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------|-------|------------------------|-------------------------|
|                                                                                                                                                            | F        | P-value <sup>1</sup> | Range | Power low <sup>2</sup> | Power high <sup>2</sup> |
| American Robin                                                                                                                                             | 1.7      | 0.21                 | 0.5   | 0.4                    | 0.9                     |
| Brown Creeper <sup>2</sup>                                                                                                                                 | 2.0      | 0.14                 | n/a   | n/a                    | n/a                     |
| Chestnut-backed Chickadee                                                                                                                                  | 1.5      | 0.29                 | 0.5   | 0.1                    | 0.5                     |
| Dark-eyed Junco                                                                                                                                            | 2.0      | 0.15                 | 0.5   | 1.0                    | 1.0                     |
| Golden-crowned Kinglet                                                                                                                                     | 0.8      | 0.50                 | 0.5   | 0.2                    | 0.6                     |
| Hammond's Flycatcher                                                                                                                                       | 13.6     | <b>&lt;0.0001</b>    | n/a   | n/a                    | n/a                     |
| Hairy Woodpecker                                                                                                                                           | 1.1      | 0.38                 | 0.3   | 0.5                    | 0.9                     |
| Hermit Thrush                                                                                                                                              | 0.1      | 0.98                 | 0.5   | 1.0                    | 1.0                     |
| Pine Siskin <sup>2</sup>                                                                                                                                   | 0.5      | 0.70                 | n/a   | n/a                    | n/a                     |
| Pacific-slope Flycatcher                                                                                                                                   | 1.96     | 0.15                 | 0.5   | 0.6                    | 1.0                     |
| Red-breasted Sapsucker                                                                                                                                     | 0.6      | 0.75                 | 0.3   | 1.0                    | 1.0                     |
| Red Crossbill <sup>2</sup>                                                                                                                                 | 4.3      | <b>0.02</b>          | n/a   | n/a                    | n/a                     |
| Steller's Jay                                                                                                                                              | 2.2      | 0.12                 | 0.3   | 0.9                    | 1.0                     |
| Swainson's Thrush                                                                                                                                          | 1.1      | 0.37                 | 0.5   | 0.1                    | 0.3                     |
| Townsend's Warbler                                                                                                                                         | 1.3      | 0.29                 | 0.5   | 1.0                    | 1.0                     |
| Violet Thrush                                                                                                                                              | 2.8      | <b>0.06</b>          | 0.5   | 0.5                    | 0.9                     |
| Vaux's Swift                                                                                                                                               | 0.6      | 0.73                 | 0.3   | 0.6                    | 1.0                     |
| Winter Wren                                                                                                                                                | 2.4      | <b>0.10</b>          | 0.5   | 0.5                    | 0.9                     |
| Total individuals <sup>3</sup>                                                                                                                             | 2.5      | <b>0.09</b>          | n/a   | n/a                    | n/a                     |
| Species richness                                                                                                                                           | 4.2      | <b>0.02</b>          | n/a   | n/a                    | n/a                     |
| Modified Shannon-Wiener diversity                                                                                                                          | 1.8      | 0.17                 | 3     | 0.8                    | 1.0                     |
| rank transformed data                                                                                                                                      |          |                      |       |                        |                         |
| log transformed data                                                                                                                                       |          |                      |       |                        |                         |
| <sup>1</sup> P <sub>2</sub> ≤ 0.05 is bolded, 0.05 < P <sub>2</sub> 0.1 is italicized                                                                      |          |                      |       |                        |                         |
| <sup>2</sup> Minimum (power low) and Maximum (power high) retrospective power is presented because there are more than two levels of the factor "Position" |          |                      |       |                        |                         |

**Figure 3.** Least square means and standard errors (unranked data) for the 4 positions of survey points from the rivers for significant tests ( $\alpha=0.05, 0.10$ ) of the completely randomized, split-plot design ANOVA. An asterisk (\*) indicates rank transformed data were used to fit the model.



Crossbills and species richness were greater away from the river (Figure 3). As well, the mean numbers of Varied Thrush, Winter Wren, and total individuals were greater away from the river at the 90% level of significance (Figure 3). The ANOVAs for Dark-eyed Junco, Hermit Thrush, Red-breasted Sapsucker, Steller's Jay, Townsend's Warbler, and community diversity appear to have had adequate power at the estimated practical differences for determining that mean abundance of these species and community diversity did not change with position.

### 4.1.3 INTERACTIONS

Significant interactions were determined for two species. Mean abundance at position depended on watershed for both Hammond's Flycatchers ( $F=4.2$ ,  $P=0.02$ ) and Townsend's Warblers ( $F=3.3$ ,  $P=0.04$ ). The mean abundance of Hammond's Flycatchers, when tested separately within watershed, showed similar patterns, with mean abundance declining away from the river (Tsitika R.,  $F=3.1$ ,  $P=0.06$ ; Davie R.,  $F=9.8$ ,  $P=0.01$ ). The interaction for Townsend's Warbler occurs because mean abundance in the 250-350 m and 375-475 m intervals in the Tsitika R. watershed have opposite trends to those in the Davie R. watershed. Yet abundance did not change significantly for Townsend's Warblers when watersheds were tested separately (Tsitika R.,  $F=1.0$ ,  $P=0.42$ ; Davie R.,  $F=1.4$ ,  $P=0.33$ ).

### 4.2 TERRITORY MAPPING

More species were detected in the old-growth forest using the point count survey method (31 species) compared with the mapping method (18 species). This is likely because the mapping method only includes breeding territories and had fewer replicates. Bird communities in the control study blocks included species that are normally associated with old-growth forest and species that use riparian edge for breeding and foraging (Appendix A). Study blocks with riparian forest buffers included bird species found in old-growth, bird species of young plantations, bird species of the forest edge produced by the interface of young plantation and old-growth forest buffer, and bird species of the riparian edge (Appendix A).

Renkonen percent similarities calculated for each watershed between the control block and the blocks with riparian forest buffers were low (Table 5), expressing the more diverse nature of the habitat in the study blocks with riparian forest buffers. Renkonen percent similarities calculated between treatments within watersheds were variable and the results were not consistent for the two watersheds. Differences between communities between the two watersheds were further demonstrated by the lower percent similarities (45%-67%) calculated between watersheds for the same treatments (Table 5).

Proportions of bird species in the communities in the single and double buffer study blocks were more similar to each other (Table 5), as expected given the similar mixture of available habitat types. But some differences in species and abundance indicate that both site and buffer design may also influence habitat values. In the Tsitika R. watershed, the study block with the double wide buffer was 50% similar to the control study

**Table 5.** Renkonen Percent Similarity between the unlogged control study blocks and plantations with riparian forest buffers within and between the two watersheds (CN control, DN double narrow buffer, SN single narrow buffer, DW double wide buffer). Maximum overlap is 100%.

| Comparison within watersheds                          | Tsitika R. (%) | Davie R. (%) |
|-------------------------------------------------------|----------------|--------------|
| CN:SN                                                 | 16             | 36           |
| CN:DN                                                 | 24             | 52           |
| DN:SN                                                 | 45             | 76           |
| DW:CN                                                 | 50             | n/a          |
| DW:DN                                                 | 57             | n/a          |
| DW:SN                                                 | 49             | n/a          |
| Comparison between Tsitika R. and Davie R. watersheds |                |              |
| CN:CN                                                 | 67             |              |
| DN:DN                                                 | 45             |              |
| SN:SN                                                 | 46             |              |

block, yet the study block with the double wide buffer was also similar (49-57%) to those blocks with the narrow buffers.

Several species were exclusive to the old-growth controls, including Merlin, Marbled Murrelet, Gray Jay and Townsend's Warbler. Species exclusive to the young plantations included Orange-crowned Warbler, MacGillivray's Warbler, Song Sparrow, White-crowned Sparrow, and Rufous Hummingbird (although this species does breed in mature forest: pers. obser., Carey 1988). Species associated with riparian habitats included Warbling Vireo in a control and a Common Yellowthroat in a buffer; both were incidental breeders. Species often found associated with edges that used the buffers included Northern Flicker, Olive-sided Flycatcher, Violet-green Swallow, Western Tanager and Steller's Jay (Appendix A).

Number of territories per hectare of total breeding individuals per study block tended to decline in both watersheds as the amount of old-growth forest cover declined from 100% in controls to <30% in the plantations with riparian forest buffers (Figure 4). Species richness per hectare per study block only tended to decline with the decline from 100% canopy cover in the Davie R. watershed (Figure 4). The addition of new species associated with the different habitats such as edge and young plantation had the effect of elevating or retarding species richness, although other species were eliminated with removal of the old-growth forest (Appendix A). Study blocks with double buffers (narrow or wide) had more territories and maintained a broader range of species than those with the single buffers in both watersheds (Figure 4). Species detected in both double buffers and control blocks but not single buffers included: Brown Creeper, Hairy Woodpecker, Red-breasted Sapsucker, Swainson Thrush, Varied Thrush, Hermit Thrush, and Pacific-slope Flycatcher.

Response of breeding individuals and species richness differed between the study block with the narrow double buffer and the study block with the one wide buffer along the Tsitika R. Species

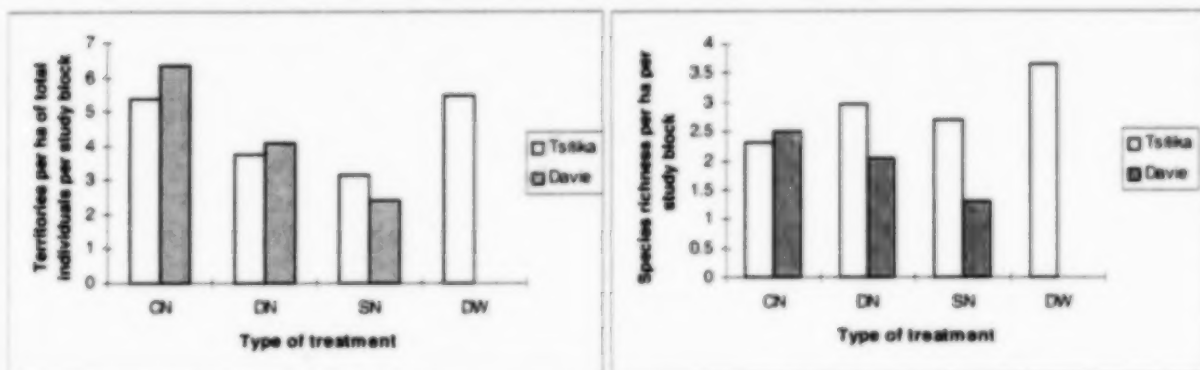


**Figure 4.** Number and richness of breeding forest birds surveyed in the controls and three types of treatments (control CN, double narrow buffer DN, single narrow buffer SN, and double wide buffer DW) in the Tsitika R. and the Davie R. watersheds.

richness and total number of individuals in the wide buffer study block exceeded that measured for the controls and for the study blocks with double or single narrow buffers (Figure 4). The overall mixture of species in the wide buffer expresses both the variety of habitats available, as well as the greater amount of habitat available for species with larger territories (Appendix A). The study blocks with narrow buffers were characterized by young plantation and edge species, as well as those species with smaller territories (Appendix A).

## 5 DISCUSSION

### 5.1 INFLUENCE OF BROAD ECOSYSTEMS

Abundance of individual species and community diversity between the two watersheds may differ in part because of geographic variation (Hansen et al. 1995). Habitat selectivity of species can be associated with the prevailing characteristics of the broad ecosystem (in this study described by subzone; Meidinger and Pojar 1991), including climate, vegetation and forest structure. Diversity was greater in the CWHxm (Davie R. watershed). The CWHxm has a warmer, drier climate that may be more productive for breeding (temperature) and foraging (insect productivity) of species compared with the cooler, wetter CWHvm1 (Tsitika R. watershed).

Yet individual species are adapted to the varying conditions of the prevailing habitat. Similar to our results, Pacific-slope Flycatchers and Winter Wrens in the Washington and Oregon Cascade Ranges are found in greater abundance within wet old-growth stands, while Hammond's Flycatchers, Hermit/Townsend's Warblers, Hermit Thrushes and Dark-eyed Juncos are in higher numbers in mesic and dry stands (Gilbert and Allwine 1991, Manuwal 1991). Hammond's Flycatchers and Townsend's Warblers were also strongly associated with the CWHxm and Pacific-slope Flycatchers with the CWHvm1 during a chronosequence study in the same general area on Northern Vancouver Island (Deal and Lessard 1995).

Differences in community structure between the two watersheds

may also in part be attributable to differences in available adjacent habitat in the landscape and to differences between the riparian forest buffer design and harvesting histories. For example, site-tenacious species can return 1-2 years following harvest, although they might decline after several years (Darveau et al. 1995).

Association of species with habitat is also often correlated with stand structures (Gilbert and Allwine 1991, Huff et al. 1991). Brown Creepers are bark insectivores and their greater abundance in the Davie R. watershed was likely associated with the availability of thick bark on the old-growth Douglas-fir used as a foraging substrate (Huff et al. 1991). Presence of flycatchers may also be related to dominant vegetation types. In the Oregon Cascade Range, medium-large Douglas-fir trees such as those found in the Davie R. watershed are important for Hammond's Flycatchers, while Pacific-Slope Flycatchers avoid medium-large Douglas-fir trees (Gilbert and Allwine 1991). Red Crossbills are canopy seed eaters; different species of crossbills specialize on seeds from different tree species and their abundance is associated with cone crop availability (Huff et al. 1991, Benkman 1993). Cone crop availability in 1994 may have been better in the Tsitika R. watershed if this was a poor or moderate year for cone crop, because cone crop availability during poorer periods may differ by location or by tree species (L. Sigurdson pers. comm.). Therefore, the broader ecosystem containing both riparian and upland habitat may have a strong influence on the occurrence of some species.

### 5.2 RIPARIAN TO UPLAND GRADIENT

Species richness in the riparian zone compared with the upland is in part attributable to the edge interface, the associated streamside deciduous vegetation, and the more developed vertical strata (Murray and Stauffer 1995). Yet, in the unlogged old-growth, the Hammond's Flycatcher was the only species that selected habitats influenced by the conditions adjacent to the mid-reaches of the rivers. This response similarly has been observed in mesic to dry, interior montane spruce habitats of British Columbia (Kinley and Newhouse 1997). Hammond's

Flycatchers are aerial insectivores also associated with deciduous trees (Gilbert and Allwine 1991, Lock and Naiman 1998). Deciduous trees in our study area were mostly found along riparian edges. Canopy gap may also enhance foraging for Hammond's Flycatchers with the openings above the rivers providing preferred habitat. Riparian obligates, which depend on the availability of free water for stages of their life history, were not detected at the rivers (Bunnell et al. 1995).

The number of samples proved inadequate for determining selectivity of the riparian habitats for some species, and we may have been unable to detect a finer shift in species abundance and distance to river because the survey points were located at a relatively broad scale (150 m intervals) compared with the riparian zone. For those species for which sample size appeared adequate, our methodologies may not have detected preference for riparian habitat if species were rare, occupied a zone wider than the riparian area, or responded to availability of riparian habitat at a finer scale (Wiebe and Martin 1998).

Several species were more abundant in the upland, and this was likely due to finer-scale availability of habitat. For example, the Winter Wren responds to riparian habitat provided by smaller streams (e.g., S3-S5), and this is available at a finer scale within both the riparian and upland habitat adjacent to larger streams (e.g., S1) (McGarigal and McComb 1992, Waterhouse 1998). The greater abundance of Red Crossbills in the upland may have occurred if the cone crop was produced throughout the canopy (Leadem et al. 1997) and increased with the increase in stem densities of conifers away from the rivers (Gregory 1997). Greater abundance of Varied Thrushes may also have been associated with higher densities of smaller-diameter trees (10-30 cm dbh) and snags in the upland (Savard et al. 1999).

The riparian areas of these coastal ecosystems, are unlike those in interior regions because coastal riparian areas appear to support fewer individuals and species than the upland (McGarigal and McComb 1992, Kinley and Newhouse 1997, Lock and Naiman 1998). Yet diversity remained unchanged between riparian and upland in the study areas, revealing a relatively uniform bird community structure between the two habitats. This uniform structure in turn likely reflects a relatively uniform gradient of habitat values from riparian to upland, and finer-scale habitat selectivity by birds.

The riparian areas in the unharvested old-growth commonly included the same species found in the upland habitat. In part this may be attributable to the relatively narrow riparian zones along the middle reaches of the rivers and the relatively uniform gradients between the streamside and upland habitats (Gregory et al. 1991, Murray and Stauffer 1995, LaRue et al. 1995, Gregory 1997). In the boreal forest, LaRue et al. (1995) found similarities in the use of riparian and upland habitats along smaller streams for tree foraging (e.g., Chestnut-backed Chickadee) and tree bole species (e.g., Red-breasted Nuthatch and Brown Creeper), although some species exclusively used the riparian edge (e.g., Northern Waterthrush) or showed preference for the riparian edge (e.g., Winter Wren).

Similarly, McGarigal and McComb (1992) in forests of the

central Oregon Coast Range found that species broadly overlap in use of riparian and upland habitat of smaller streams, although some of these species were more abundant in the upland habitat (Brown Creepers and Chestnut-backed Chickadees), while others were more abundant in riparian habitat (Winter Wrens and Swainson Thrushes). Species assemblages, as our results demonstrate, interact between the riparian and upland and are not independent units (Knopf and Samson 1994).

### 5.3 WIDTHS OF RIPARIAN FOREST BUFFERS FOR BIRDS

Riparian forest buffers should include both riparian and upland areas for maintaining the natural richness and diversity of the associated bird community following harvesting (Triquet et al. 1990, McGarigal and McComb 1992, Croonquist and Brooks 1993, Spackman and Hughs 1995). The maximum number of species detected within the two watersheds was within 350 m of the rivers. This indicates that wide buffers are more likely to provide sufficient habitat to retain numbers and kinds of breeding individuals similar to unfragmented forest (Kinley and Newhouse 1997, Hager 1999). However, habitat values of contiguous forest are not equivalent to those in buffers because fragments can have reduced interior forest, more edge, and increased isolation (Wiens 1995). For example, edges attract nest predators, although wider buffers may help reduce edge effect by supporting greater dispersal of nests thus reducing encounters with predators (Gates and Griffen 1991).

Researchers on streams smaller than those examined in this study determined that: riparian forest buffers of a minimum 60 m width were needed to maintain forest dwelling birds in eastern boreal forests (Darveau et al. 1995); riparian forest buffers 75-175 m wide were needed to include 90% of the species in eastern mixed hardwood forests of Vermont (Spackman and Hughs 1995); and riparian forest buffers <70 m wide would not maintain all species found in unlogged mature forest control sites in the central Oregon Coast Range (Hager 1999). Increased species richness is demonstrated in wider buffer strips in other habitats such as woodland and agriculture (Stauffer and Best 1980). The wide buffer surveyed in this study ranged between 50 and 120 m (mean ~85 m) in width but failed to retain the intact bird community found in the unharvested old-growth (12 of the 18 species, 50% Renkonen Percent Similarity).

Reduction of the contiguous forest to narrow strips produced habitat more favourable for young seral stage and edge species. However, the narrower riparian forest buffers (<50 m) had limited value for cavity users and species with large territories. In the Tsitika R. watershed, species richness in the mixed habitats of buffer and plantation exceeded that in old-growth, although this is not unexpected since more open area species occupy the mixed habitat as it matures. The mixture of species that occurred in stands with riparian forest buffers in this study was similar to the mixture found in a study of coniferous/hardwood lakeshore habitat (Johnson and Brown 1990) where edge and the early successional stage influence species composition, and where some species such as cavity nesters (e.g., Pileated Woodpecker, Red-breasted Nuthatch and Brown Creeper) are not found

breeding. Riparian forest buffers instead tended to better support foraging guilds including bark, aerial and ground foragers – for example, Brown Creeper, Chestnut-backed Chickadee, and Winter Wren (Johnson and Brown 1990). Overall the riparian forest buffers contribute to bird diversity within a harvested area by maintaining species that appear to select riparian edge and some old forest species, and by providing a more diverse habitat than plantations lacking structural remnants (Triquet et al. 1990).

## 5.4 BUFFERS AS HABITAT FOR BIRDS

The importance of the role of riparian forest buffers for providing habitat was emphasized through contrasting double narrow and single narrow buffers. Single narrow buffers opposing unharvested old-growth forest appeared to have more limited value as habitat for breeding birds. This suggests that species may have preferred to use the contiguous forest on the opposing side of the river instead of the buffer. These single narrow buffers in the context of plantations mostly supported species with smaller territories (<0.5 ha) and some species that use the riparian edge. The higher use of the double narrow buffers in turn suggests the role of a potential habitat sink, where the fragment provides alternate habitat among younger plantations for species associated with the old-growth but reproduction within the fragment may not necessarily sustain populations (Pulliam 1988).

Riparian forest buffers may thus help maintain some bird species in a local area, particularly over the long term if habitat structure is restored as the plantation matures. However, habitat quality for foraging and successful breeding of birds may be reduced or vary with the width of the riparian forest buffer in the short term.

## 6 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

For this research we defined the old-growth bird community in two ways. First we defined it as the community that contained those bird species using old-growth forest during the breeding season (presence during a point count survey; Appendix A). Second, we defined it as the community that contained those bird species which were known to breed in the forest (following delineation of territories with mapping; Appendix A).

The riparian forest buffers that we studied were established prior to the Forest Practices Code and in general were less than 30 m wide. Today, the Riparian Management Area Guidebook for the Forest Practices Code (Government of BC 1995) specifies riparian forest buffer widths that are intended to prevent or minimize impacts of forest and range use on the diversity, productivity, and sustainability of wildlife habitat and vegetation adjacent to streams with reserve zones, or where high wildlife values are present. The Tsitika and Davie Rivers are S1 streams and now require 50 m reserve zones and additional 20 m management zones.

The riparian forest buffers we studied provided habitat for some breeding birds associated with the old-growth forest bird

community. They may also help maintain natural bird diversity through protection of the riparian edge. However, we found that abundance and richness of species were affected by the distance to the rivers and we found that a wider riparian forest buffer appears to support more species in common with the old-growth bird community. These results suggest that although narrow buffers maintain some habitat value for the species found in the old-growth bird community, the lack of available old-growth forest in the upland may be limiting for other bird species.

The old-growth bird community in this study was not simply stratified between riparian and upland habitats. Some species were more strongly associated with one or the other habitat, and some species have territories or home ranges for breeding and foraging that incorporate both habitats. Buffer widths maximized to include both riparian and upland habitat will likely provide better-quality habitat for the old-growth bird community than those with just riparian habitat. Wider buffers will provide for more species of the old-growth bird community and maintain a greater portion of this community over the long term. The 50 m riparian reserve zones and adjacent 20 m riparian management zones now provided for on S1 rivers under the Forest Practices Code (Government of BC 1995) will therefore likely provide better habitat for the old-growth forest bird community than the narrower riparian buffers reserved in the past (Province of BC 1993).

However, habitat that supports many of those species associated with the old-growth bird community may become available as the plantation matures, if important habitat attributes (e.g., snags, downed wood) and habitat structure (vertical and horizontal heterogeneity) are managed for before and following harvest (Eckert et al. 1992, Bryant et al. 1993, Deal and Lessard 1995, Savard et al. 1999). Over the long term, the riparian forest buffer, although subject to small-scale disturbance, should provide stable habitat for some species, while the adjacent forest supports different bird communities as it shifts between immature and mature seral stages. Bird community diversity which is lower in young closed stands with fewer environmental resources may recover as the stand matures (Franklin and Spies 1991).

Managers should be cognizant that the importance of remnant habitat attributes, including those available in riparian forest buffers, will likely be amplified in these second-growth forests, because compared with old-growth forest their availability will be reduced with the change in stand structure (Franklin and Spies 1991, Wells 1996). Therefore the long-term value of riparian forest buffers as high-quality bird habitat for some species may potentially be reduced because of overly high usage by both old-growth associated species and edge species, or avoidance by old-growth associated species. Retention of old trees, snags in wildlife tree patches, and large downed wood throughout the stand at harvest may help ensure that second-growth forests maintain important habitat attributes outside of the riparian management area, and maintain high-quality habitats for birds over the long term as the buffer is incorporated into a more mature forest matrix (Hunter 1990, Franklin et al. 1997).

Silvicultural practices including spacing, partial cutting and/or

commercial thinning have the potential to enhance stand structure for improving the availability of environmental resources in the developing forest and to better retain a structural gradient between riparian and interior forest. However, these practices will also alter bird community composition and individual species response because the value of foraging and breeding habitats change with change in vegetation and stand structure (Hansen et al. 1995).

Our comparison of double to single riparian forest buffers suggests that as an alternative to retaining wider riparian forest buffers (i.e., >70 m riparian management areas), a larger portion of the old-growth bird community might in the short term be retained by reducing the isolation of riparian forest buffers from interior forest habitats (i.e., the double buffer situation). Retaining mature habitat across the river from the riparian forest buffer, while it is bounded by a young plantation, is one option that may reduce limitations of buffer area on some species. Both of the riparian edges would also remain protected for bird habitat. Species that might immediately benefit include those species with larger territories that use riparian habitats, and those species which prefer more interior forest conditions. In addition this would potentially reduce species packing in riparian forest buffers, as well as predation and exposure on the forest/plantation edge.

## 7 FUTURE RESEARCH

Results from the study were limited statistically because it is a pilot study. Future research should include expansion of the sampling design and testing the effectiveness of present regulations for maintenance of riparian habitat. The study focus did not include measures of reproductive success or foraging behaviour, and these are important measures on habitat use and quality (Van Horne 1983). It is also important to study habitat values of riparian areas during the winter because many of the bird species that are associated with old-growth forest are winter residents (Savard et al. 1999). Our research also did not specifically address habitat needs in relation to riparian forest buffers of strongly associated old-growth species (e.g., Marbled Murrelet), or uncommon or low-density species (e.g., Pileated Woodpecker).

We only evaluated riparian buffers on one stream class, yet riparian forest buffers are managed at various scales (small to large streams, S1-S6 (Government of British Columbia 1995)). Many bird species will likely differentially respond to availability of these different-sized water courses (Lock and Naiman 1998). For example, the upland area of a large stream may be important for a species because it contains the riparian area of a smaller stream. Further research is required to understand the scale effects of riparian habitats on birds.

In addition, although management of riparian forest buffers as a stand level practice is important, it fails to address maintenance of bird species within a landscape. For example, the gradient from headwater to estuary in a watershed also contributes to species diversity but needs to be managed for at the landscape level (McGarigal and McComb 1992, Wiebe and Martin 1998).

To address the broadest scale of management for bird diversity we need to understand how to incorporate landscape differences, because species response can change with geographic variation, and therefore differences in riparian buffer widths may need to be adjusted to capture differences in habitat values. For example, the importance of riparian habitat for some species may be increased in drier ecosystems.

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## APPENDIX A

Occurrence of species by habitat using survey points for total detections and mapping of breeding territories in all study blocks.

| Species                        | Survey points     | Study blocks      |                    |                      |                      |                       |
|--------------------------------|-------------------|-------------------|--------------------|----------------------|----------------------|-----------------------|
|                                | Old-growth forest | Old-growth forest | Double wide buffer | Double narrow buffer | Single narrow buffer | Plantation (<4 years) |
| American Robin                 | X                 | X                 | X                  | X                    | X                    | X                     |
| <i>Turdus migratorius</i>      |                   |                   |                    |                      |                      |                       |
| Winter Wren                    | X                 | X                 | X                  | X                    | X                    | X                     |
| <i>Troglodytes troglodytes</i> |                   |                   |                    |                      |                      |                       |
| Chestnut-backed Chickadee      | X                 | X                 | X                  | X                    | X                    |                       |
| <i>Parus rufescens</i>         |                   |                   |                    |                      |                      |                       |
| Golden-crowned Kinglet         | X                 | X                 | X                  | X                    | X                    |                       |
| <i>Regulus satrapa</i>         |                   |                   |                    |                      |                      |                       |
| Hammond's Flycatcher           | X                 | X                 | X                  | X                    | X                    |                       |
| <i>Empidonax hammondi</i>      |                   |                   |                    |                      |                      |                       |
| Brown Creeper                  | X                 | X                 |                    | X                    | X                    |                       |
| <i>Certhia americana</i>       |                   |                   |                    |                      |                      |                       |
| Hairy Woodpecker               | X                 | X                 | X                  | X                    |                      |                       |
| <i>Picoides villosus</i>       |                   |                   |                    |                      |                      |                       |
| Red-breasted Sapsucker         | X                 | X                 | X                  | X                    |                      |                       |
| <i>Sphyrapicus ruber</i>       |                   |                   |                    |                      |                      |                       |
| Swainson's Thrush              | X                 | X                 | X                  | X                    |                      |                       |
| <i>Catharus ustulatus</i>      |                   |                   |                    |                      |                      |                       |
| Varied Thrush                  | X                 | X                 | X                  | X                    |                      |                       |
| <i>Ixoreus naevius</i>         |                   |                   |                    |                      |                      |                       |
| Hermit Thrush                  | X                 | X                 | X                  |                      |                      |                       |
| <i>Catharus guttatus</i>       |                   |                   |                    |                      |                      |                       |
| Pacific-slope Flycatcher       | X                 | X                 | X                  |                      |                      |                       |
| <i>Empidonax difficilis</i>    |                   |                   |                    |                      |                      |                       |
| Steller's Jay**                | X                 | X                 | X                  |                      |                      | X                     |
| <i>Cyanocitta stelleri</i>     |                   |                   |                    |                      |                      |                       |
| Townsend's Warbler             | X                 | X                 |                    |                      |                      |                       |
| <i>Dendroica townsendi</i>     |                   |                   |                    |                      |                      |                       |
| Merlin                         | X                 | X                 |                    |                      |                      |                       |
| <i>Falco columbarius</i>       |                   |                   |                    |                      |                      |                       |



## Appendix A continued:

| Species                         | Survey points     |                   | Study blocks       |                      |                      |                       |
|---------------------------------|-------------------|-------------------|--------------------|----------------------|----------------------|-----------------------|
|                                 | Old-growth forest | Old-growth forest | Double wide buffer | Double narrow buffer | Single narrow buffer | Plantation (<4 years) |
| Marbled Murrelet                | X                 | X                 |                    |                      |                      |                       |
| <i>Brachyramphus marmoratus</i> |                   |                   |                    |                      |                      |                       |
| Gray Jay                        | X                 | X                 |                    |                      |                      |                       |
| <i>Perisoreus canadensis</i>    |                   |                   |                    |                      |                      |                       |
| Warbling Vireo*                 | X                 | X                 |                    |                      |                      |                       |
| <i>Vireo gilvus</i>             |                   |                   |                    |                      |                      |                       |
| Barred Owl                      | X                 |                   |                    |                      |                      |                       |
| <i>Strix varia</i>              |                   |                   |                    |                      |                      |                       |
| Red Crossbill                   | X                 |                   |                    |                      |                      |                       |
| <i>Loxia curvirostra</i>        |                   |                   |                    |                      |                      |                       |
| Pine Siskin                     | X                 |                   |                    |                      |                      |                       |
| <i>Carduelis pinus</i>          |                   |                   |                    |                      |                      |                       |
| Red-breasted Nuthatch           | X                 |                   |                    |                      |                      |                       |
| <i>Sitta canadensis</i>         |                   |                   |                    |                      |                      |                       |
| Pileated Woodpecker             | X                 |                   |                    |                      |                      |                       |
| <i>Dryocopus pileatus</i>       |                   |                   |                    |                      |                      |                       |
| Common Raven**                  | X                 |                   |                    |                      |                      |                       |
| <i>Corvus corax</i>             |                   |                   |                    |                      |                      |                       |
| Vaux's Swift                    | X                 |                   |                    |                      |                      |                       |
| <i>Chaetura vauxi</i>           |                   |                   |                    |                      |                      |                       |
| MacGillivray's Warbler          | X                 |                   |                    |                      |                      | X                     |
| <i>Oporornis tolmiei</i>        |                   |                   |                    |                      |                      |                       |
| Rufous Hummingbird              | X                 |                   |                    |                      |                      | X                     |
| <i>Selasphorus rufus</i>        |                   |                   |                    |                      |                      |                       |
| Song Sparrow                    | X                 |                   |                    |                      |                      | X                     |
| <i>Melospiza melodia</i>        |                   |                   |                    |                      |                      |                       |
| Dark-eyed junco                 | X                 |                   |                    | X                    |                      | X                     |
| <i>Junco hyemalis</i>           |                   |                   |                    |                      |                      |                       |
| Northern Flicker                | X                 |                   |                    | X                    |                      |                       |
| <i>Colaptes auratus</i>         |                   |                   |                    |                      |                      |                       |
| Western Tanager**               | X                 |                   |                    | X                    |                      |                       |
| <i>Piranga ludoviciana</i>      |                   |                   |                    |                      |                      |                       |
| Ruffed Grouse**                 |                   |                   | X                  |                      |                      |                       |
| <i>Bonasa umbellus</i>          |                   |                   |                    |                      |                      |                       |
| Common Yellowthroat*            |                   |                   | X                  |                      |                      |                       |
| <i>Geothlypis trichas</i>       |                   |                   |                    |                      |                      |                       |
| Violet-green Swallow**          |                   |                   | X                  | X                    |                      |                       |
| <i>Tachycineta thalassina</i>   |                   |                   |                    |                      |                      |                       |
| Olive-sided Flycatcher**        |                   |                   | X                  | X                    |                      |                       |
| <i>Contopus borealis</i>        |                   |                   |                    |                      |                      |                       |
| Orange-crowned Warbler          |                   |                   |                    |                      |                      | X                     |
| <i>Vermivora celata</i>         |                   |                   |                    |                      |                      |                       |
| White-crowned Sparrow           |                   |                   |                    |                      |                      | X                     |
| <i>Zonotrichia leucophrys</i>   |                   |                   |                    |                      |                      |                       |

\*known associate of riparian (Erhlich et al. 1988, Campbell et al. 1997)

\*\*known associate of edge (Erhlich et al. 1988, Campbell et al. 1997)

